*Le Infezioni in Medicina, n. 4, 429-439, 2023*
doi: 10.53854/liim-3104-2



# Synergistic fight against future pandemics: Lessons from previous pandemics

**Olalekan John Okesanya[1,2], Gbolahan Olatunji[3], Emery Manirambona[4], Mba Mercy Oluebube[5], Abdu-Samad Adebayo Rasheed[2,6], Noah Olabode Olaleke[2,7], Aderonke Cecilia Ogunlayi[1], Jerico B. Ogaya[8], Elijah Kolawole Oladipo[9], Olumuyiwa Ayokunle Igbalajobi[10], Tolutope Adebimpe Oso[1], Don Eliseo Lucero-Prisno III[12]**

[1]Department of Medical Laboratory Science, Neuropsychiatric Hospital, Aro, Abeokuta, Nigeria;
[2]Department of Medical Laboratory Science, Kwara State University, Ilorin, Kwara State, Nigeria;
[3]Department of Medicine and Surgery, University of Ilorin, Kwara State, Nigeria;
[4]College of Medicine and Health Sciences, University of Rwanda, Kigali, Rwanda;
[5]Department of Physiotherapy, David Umahi Federal University Teaching Hospital, Uburu, Ebonyi State, Nigeria;
[6]Department of Medical Laboratory Science, Federal Medical Centre Abeokuta, Ogun State, Nigeria;
[7]Obafemi Awolowo University Teaching Hospital Complex, Ile-Ife, Osun State, Nigeria;
[8]Department of Medical Technology, Far Eastern University, Manila, Philippines;
[9]Department of Microbiology, Laboratory of Immunology, Molecular Biology and Bioinformatics, Adeleke University, Ede, Osun State, Nigeria;
[10]Department of Biology, Ambrose University, Calgary, Alberta, Canada;
[11]Department of Global Health and Development, London School of Hygiene and Tropical Medicine, London, United Kingdom

*Article received 21 July 2023; accepted 10 October 2023*

## SUMMARY

The history of pandemics spans centuries and has had a profound impact on human health, societies, and economies. Pandemics have caused fear, panic, and significant morbidity and mortality rates throughout history. From the Athenian Plague in 430 BC to the ongoing COVID-19 pandemic, infectious diseases have posed a continuous threat to global health systems. The transition from hunter-gatherer societies to agrarian communities, increased trade and interaction between humans and animals, urbanization, travel rates, and the impact of a growing human population have all contributed to the emergence and spread of infectious diseases. Climate change and changes in land use further affect the transmission of pathogens and the distribution of disease-carrying vectors. Lessons from previous pandemics include the importance of early diagnosis and response, global cooperation and collaboration, strengthened healthcare systems, preparedness planning, public health education and communication, research and development, and adaptability and flexibility in response strategies. These lessons emphasize the significance of timely identification, swift action, sharing information and resources, investing in healthcare infrastructure, preparedness planning, effective communication, research advancements, and the ability to adapt measures as pandemics evolve. In addition, the COVID-19 pandemic has reinforced the need for a collaborative and coordinated global response to future pandemics. Governments, international bodies, healthcare organizations, and individuals could learn from the lessons of the past and apply them effectively to combat and mitigate the impact of future outbreaks. By prioritizing all the recommendations stated, the world can synergistically protect public health and minimize the devastating consequences of pandemics.

*Keywords:* Pandemic, epidemics, outbreak, infectious diseases, humans, epidemiology.

*Corresponding author*
Okesanya Olalekan John,
Email: okesanyaolalekanjohn@gmail.com

## INTRODUCTION

The term "pandemic" was initially introduced in 1666 to describe a disease that was rapidly spreading within a country [1]. During the 17th and 18th centuries, both "epidemic" and "pandemic" were used interchangeably and broadly in various social and medical contexts [2]. From ancient times to the present, epidemics and pandemics have caused fear and panic, resulting in high morbidity and mortality rates and the economic destruction of affected nations [3]. The world has witnessed various epidemics and pandemics throughout history, including recent examples such as the Zika virus, Spanish flu, H1N1 influenza virus, and the current COVID-19 pandemic caused by the SARS-CoV-2 virus [4]. Despite advancements in medical science, the threat of pandemics remains a significant concern, as these outbreaks have exposed the vulnerability of global health systems [5]. In the absence of international attention, future epidemics have the potential to surpass previous outbreaks in terms of severity and impact. Moreover, countries within the World Health Organization are currently engaged in discussion of a global accord on pandemic prevention, preparedness, and response, using the "zero draft" as the basis for an agreement aimed at protecting nations and communities from future pandemic emergencies [6].

The transition from hunter-gatherer societies to agrarian communities has led to the spread of infectious diseases among humans. Increased trade and interaction between humans and animals have facilitated the transmission of zoonotic pathogens [7]. Additionally, the growth of cities, extensive trade networks, higher travel rates, and the impact on ecosystems due to a larger human population have further contributed to the emergence and spread of infectious diseases [8]. Consequently, the risks of outbreaks, epidemics, and pandemics have significantly increased [4]. The transfer of pathogens from animals to humans, known as zoonotic transmission, has been a key factor in the emergence of novel infectious diseases. Interactions with animals through activities like hunting, farming, and trade have increased the chances of cross-species transmission [9]. This process involves several stages, from the pathogen infecting animals exclusively to eventually being present only in humans. The risk of transmission depends on the animal species involved, the nature of human interaction, and factors like land use and climate change [8, 10].

Climate change impacts the transmission of various pathogens carried by vectors like mosquitos and ticks, leading to the emergence of epidemics in new regions [11]. Changes in land use due to human population growth also affect the distribution of disease-carrying vectors. Controlling these vector-borne zoonotic pathogens requires implementing measures to control the vectors themselves and address the underlying drivers of transmission [11, 12]. The extended geographic spread of infectious diseases such as Cholera, Tuberculosis, Ebola, Dengue virus, Malaria, COVID-19, and other viral infections is becoming a major health concern for a significant portion of the population [8]. These diseases are exhibiting broader dissemination due to factors like the development of drug resistance, increased tolerance of mosquito vectors to insecticides, inadequate sanitation, changes in land use and climate, as well as the rise in human mobility and travel patterns. These factors collectively contribute to the wider distribution and higher prevalence of these infectious diseases [13]. In addition, certain infectious agents, including *Yersinia pestis, Bacillus anthracis*, and the variola virus, can be utilized as bioweapons, posing serious threats to humanity. These weapons may involve natural or engineered microorganisms with heightened virulence, transmissibility, or resistance to treatment. The deliberate release of these biological weapons aims to induce diseases and potentially cause death in human populations [14]. Hence, it is vital to enhance awareness, foster the sharing of information, endorse scientific expertise and exemplary approaches, deliver high-quality education, and implement advocacy initiatives at local, national, regional, and global scales as effective strategies to avert and manage outbreaks and global health crises. The ongoing COVID-19 outbreak has underscored the necessity of a collaborative effort to combat future pandemics and eliminate their devastating consequences [15].

Pandemics have historically had significant health consequences, threatening humanity. Rapidly spreading diseases like COVID-19 strain healthcare systems, limiting access to medical services and increasing mortality rates. They also have far-reaching social, economic, and political im-

pacts [16]. In light of the concluded and several ongoing outbreaks, it is expedient for the world to enhance preparedness and learn from the lessons of past pandemics to effectively combat future outbreaks [17]. This paper aims to delve into the lessons that can be derived from previous pandemics and analyze the insights gained from each pandemic. Additionally, this paper will discuss the implications of these lessons for synergistically fighting future pandemics.

## BRIEF HISTORY OF MAJOR PANDEMICS

The Athenian Plague of 430 BC had various symptoms and caused the deaths of around 25% of the Athenians. Its exact cause remains unknown, but overcrowding due to the war was believed to contribute to its spread [2]. In 165-180 AD, the Antonine Plague spread throughout the Roman Empire, resulting in an estimated 5 million deaths. It was reported to have likely been caused by smallpox and had symptoms such as rashes, fever, bloody diarrhea, cough, dyspnea, and the presence of buboes [18]. Named after the Byzantine emperor Justinian in 541 AD, this plague was caused by *Yersinia pestis* and killed an estimated 60% of the Mediterranean population [2]. The Black Death (1346-1353) also known as the bubonic plague, was one of the deadliest pandemics in history. It caused an estimated 200 million deaths and had a mortality rate of up to 60% in Europe. Its symptoms included fever, swollen lymph nodes (buboes), and severe illness leading to death [2, 17]. The cholera pandemics, starting in 1817 and continuing to the present, have caused millions of deaths globally. Cholera is transmitted through contaminated water and has led to severe diarrhea and dehydration. This pandemic is ongoing and continues to affect millions of people [8]. Between 1918 and 1919, the Spanish Flu pandemic, caused by the H1N1 influenza virus, infected approximately one-third of the world's population [20]. It resulted in an estimated 50 million deaths worldwide. The virus had a high mortality rate among young individuals [20].

The Asian Flu pandemic was caused by the H2N2 influenza virus between 1957 and 1958, and originated in China. It spread globally and caused over one million deaths. Symptoms were similar to typical influenza infections, such as fever and myalgia [21]. The Hong Kong Flu pandemic was caused by the H3N2 influenza virus, which had genetic components from both avian and 1957 pandemic strains. It spread rapidly, primarily affecting younger individuals, and caused millions of deaths worldwide between 1968 and 1969 [22]. The HIV/AIDS pandemic has had a significant impact since 1981 until the present, with millions of deaths and an ongoing global prevalence. Antiretroviral therapy helps manage the disease, but a cure remains elusive. It primarily spreads through unprotected sexual contact and contaminated blood [2, 17]. Severe Acute Respiratory Syndrome (SARS, 2002-2003) was caused by the SARS-CoV coronavirus and resulted in a global epidemic. It spread to multiple countries and caused severe respiratory symptoms, leading to 774 deaths [8]. The H1N1 influenza virus caused the swine flu pandemic between 2009 and 2010. Although it affected a large portion of the population, it had a relatively low mortality rate compared to other pandemics. Younger individuals were more susceptible to severe illnesses [23]. The Ebola virus disease between 2013 and 2016 caused a deadly pandemic primarily in West Africa, resulting in thousands of deaths. It is presented as hemorrhagic fever, with symptoms such as fever, fatigue, and gastrointestinal bleeding [24]. In 2019, COVID-19 caused by the SARS-CoV-2 coronavirus, emerged and was declared a global pandemic in 2020. It spread worldwide, resulting in millions of infections and deaths. Symptoms range from mild respiratory illness to severe complications such as acute respiratory distress syndrome (ARDS) and multi-organ failure. Vaccination efforts are underway to control the pandemic [17]. These pandemics have presented significant challenges to public health globally, as shown by the recent 2022 Monkeypox multi-country outbreak that mostly occurred in non-endemic countries without a clear cause, affecting mostly homosexuals, bisexual, and other men who have sex with Men (GBMSM) [25].

## LESSONS FROM THESE PANDEMICS

Pandemics have significantly impacted human societies, economies, and healthcare systems. Each of these pandemics has exposed our unpreparedness for public health challenges and left us with lessons to learn. As a result, governments, healthcare organizations, and individuals have learned

valuable lessons from previous pandemics that continue to shape their responses to current and future outbreaks. Below are some of the lessons learned from past pandemics.

*Early Detection and Response*

Early detection and swift response are crucial to containing the spread of a pandemic. Timely identification of cases, effective surveillance systems, and rapid implementation of control measures can help prevent or minimize the impact of a pandemic [26]. This is an important lesson from previous pandemics, emphasizing the significance of early detection and prompt response. The sooner an outbreak is identified, the more effective the measures taken to contain its transmission can be. This necessitates the establishment of a robust surveillance system capable of swiftly identifying cases and monitoring the spread of the disease [27]. To illustrate, during the SARS outbreak in 2002-2003, China received criticism for not promptly reporting the outbreak, resulting in the virus spreading to other nations [28]. However, in the case of the COVID-19 pandemic, China implemented proactive measures including lockdowns, widespread testing, and contact tracing, which played a crucial role in controlling the virus's spread [29, 30].

*Global Cooperation and Collaboration*

Pandemics transcend borders, and global cooperation is essential for sharing information, resources, and expertise. Collaborative efforts among countries, international organizations, and scientific communities are crucial for effective response and resource allocation [31, 32]. The formation of international collaborations and platforms for pandemic response can be traced back to the 19th century, following global trade and military activities. These collaborations were further institutionalized through the establishment of the World Health Organization (WHO) in 1948, which holds the responsibility and legal mandate for addressing international public health matters [33]. The COVID-19 pandemic has once again highlighted the importance of global cooperation and collaboration, with calls for solidarity, resource redistribution, and collective action. The reasons for collaboration remain consistent over time, including the recognition of shared health risks, the benefits of knowledge sharing and learning from each other's experiences, and the establishment of rules and standards to foster mutual trust and comparability of information [34]. However, despite the logical imperative to collaborate, the COVID-19 pandemic has revealed challenges and shortcomings in international collaboration, leading to criticisms of organizations like WHO and the emergence of vaccine nationalism [35]. These issues underscore the need for closer examination and resolution of problems within international health collaboration [36]. Other multilateral organizations, such as the World Bank, Gavi, and the Global Fund, have also taken on specific health agendas, but questions persist regarding their effectiveness and relationship with WHO. The COVID-19 pandemic has reignited discussions about financing and delivering global health initiatives and the need to address broader determinants of health beyond specific diseases [37]. Also, previous pandemics, including the 2009 influenza A H1N1 pandemic, have led to the establishment of collaborative platforms for infectious disease research. These platforms aim to enhance global cooperation by enabling the sharing of knowledge, resources, and data to improve research and response efforts in tackling infectious diseases [38].

*Strengthened Healthcare Systems*

Pandemics put immense pressure on healthcare systems to have robust healthcare infrastructure, adequate medical supplies, trained healthcare personnel, and surge capacity, which are crucial to ensuring a resilient healthcare system that can handle the increased demand [39]. Previous pandemics revealed that to effectively tackle future outbreaks, it is crucial to strengthen the healthcare system through improved governance, collaboration across sectors, and sufficient financial support [40]. Engaging local communities, utilizing community health workers, and adopting community-based approaches are vital for resilient health systems [5]. Investing in healthcare infrastructure, digital technology, and training for the health workforce is essential [41]. Diversifying production and ensuring a secure supply chain for medical products are important measures. Lastly, integrated systems that coordinate public health interventions and healthcare delivery are necessary for effective testing, contact tracing, and surveillance [42].

*Preparedness Planning*

Preparedness planning is the key to mitigating the impact of a pandemic. Developing and regularly updating pandemic response plans, conducting drills and simulations, and establishing communication channels among stakeholders help improve coordination and response capabilities [43]. The COVID-19 pandemic revealed that effective preparedness for future pandemics requires strong governance and leadership structures, collaborative planning processes, the development of relationships and strong networks, community engagement, robust risk analysis, surveillance and monitoring for timely information, and regular practice and experience in testing plans and processes [44]. Integrated structures, partnerships, and clear leadership are necessary for a coordinated and interoperable system. The world nowadays has learned that planning should focus on the process rather than a static document, ensuring adaptability and responsiveness [45, 46].

*Public Health Education and Communication*

Clear and consistent communication is vital during a pandemic. Educating the public about preventive measures, dispelling misinformation, and promoting public trust in healthcare authorities are essential for effective adherence to guidelines and control measures [47]. The COVID-19 pandemic has underscored the critical role of health education and effective communication in public health, particularly in promoting adherence to preventive measures to control the virus's spread. Addressing scientific uncertainties, combating rumors and misinformation, building trust in authorities, and considering ethical issues were some of the take-home for many continents during the COVID-19 pandemic [48]. The "infodemic" of true, false, and misleading information further decreased public trust, emphasizing the importance of evidence-informed communication strategies. The Crisis and Emergency Risk Communication (CERC) model, developed by the Centre for Disease Control (CDC), provides principles for communication during public health crises, emphasizing the need to be the first source of accurate information, ensure credibility and honesty, express empathy and respect, and promote actionable behavior. Overall, the pandemic has highlighted the importance of effective communication strategies tailored to the needs and values of diverse audiences to ensure public understanding, trust, and adherence to preventive measures [49].

*Research and Development*

Pandemics drive scientific research and innovation. Investing in research and development of diagnostics, treatments, and vaccines is critical for an effective pandemic response. Collaborative research efforts can lead to advancements in understanding the disease, developing therapeutics, and improving vaccination strategies [50]. The lessons learned emphasize the importance of research and development (R&D) to effectively respond to pandemics. Robust R&D, including vaccines, drugs, diagnostics, and PPE, should be prioritized and coordinated. A dedicated Pandemic Product Development Committee (PPDC) should be established to oversee R&D efforts and mobilize resources. An investment of $1 billion per year for 15 years is recommended to strengthen core functions, expand projects, and drive innovation [51]. The goal is to develop timely and effective strategies for global infectious disease outbreaks [52].

*Adaptability and Flexibility*

Flexibility in response strategies is crucial as pandemics evolve. Being able to adapt measures based on the changing nature of the pandemic, emerging variants, and scientific evidence is essential to staying ahead of the curve and effectively controlling the spread [53]. Flexibility and adaptability have emerged as critical lessons in the fight against pandemics. The ability to quickly adapt and respond to rapidly evolving situations is essential to effectively managing and mitigating the impact of a pandemic. The lessons learned highlight the importance of flexible healthcare systems that can rapidly expand capacity, reallocate resources, and adjust protocols based on emerging needs. It also emphasizes the need for adaptable public health measures that can be tailored to the different stages and characteristics of a pandemic [54]. Additionally, flexibility and adaptability extend to individuals and communities, as they need to embrace behavioral changes, such as wearing masks and practicing physical distancing, to limit the spread of the disease. By embracing flexibility and adaptability, we can enhance our ability to respond effectively and efficiently to future pandemics [55].

*Health Equity*
Pandemics often exacerbate existing health disparities. Addressing health equity issues, ensuring access to healthcare services, and addressing the needs of vulnerable populations are essential components of pandemic response and recovery efforts [56]. The COVID-19 pandemic has highlighted the presence of social inequities, discrimination, and health disparities among vulnerable populations and health systems [57-59]. To effectively fight future pandemics, it is crucial to prioritize health equity in preparedness and response plans. This includes addressing the unequal socioeconomic effects of pandemics, considering the differential impacts of containment measures, and recognizing the bidirectional relationship between socioeconomic consequences and health inequities [56]. Policy-makers and international bodies are increasingly focusing on equity, with initiatives such as task forces and equity indicators. Good governance and a comprehensive approach to health, social, environmental, and economic systems are essential for a sustainable and equitable pandemic response. The call for a new international pandemic treaty underscores the need to address health inequities in future plans [60, 61].

*Long-term Preparedness*
Pandemics serve as reminders of the ongoing need for long-term preparedness. Building resilient health systems, maintaining surveillance capabilities, investing in research and development, and continuously updating pandemic response plans are essential to being better prepared for future outbreaks [62]. Long-term preparedness is a crucial lesson learned from previous pandemics.
The COVID-19 pandemic has exposed the vulnerabilities of healthcare systems and highlighted the need for proactive measures to mitigate the impact of future outbreaks. Long-term preparedness involves investing in robust healthcare infrastructure, strengthening surveillance and early warning systems, enhancing research and development capabilities, and implementing effective communication strategies [39]. By prioritizing long-term preparedness, societies can be better equipped to respond swiftly and effectively to future pandemics, minimizing the loss of lives and economic disruptions.

## RECOMMENDATIONS TO SYNERGISTICALLY FIGHT FUTURE PANDEMICS

*Data collection and sharing*
Data collection and sharing are essential for parameterizing and evaluating models that govern predictions and scenario analysis of potential epidemic trajectories. In the course of the COVID-19 pandemic, data gathering became more organized, leading to the expansion of already-existing repositories or the creation of new ones. High-quality COVID-19 open data has been offered via volunteer-based projects like the Google GitHub repository [63]. Therefore, it is essential for governments and international organizations to commit resources to data gathering, storage, and sharing in order to effectively address upcoming pandemics and utilize a wider range of data resources. For modelling purposes, the process entails the collection, curation, and analysis of numerous forms of data. Additionally, this data's administration should follow the FAIR data principles, guaranteeing its Findability, Accessibility, Interoperability, and Reusability. The ability to access sensitive connected data, promote open access to datasets, and make it easier to track the legitimacy of model outputs all require investments in data platforms [63, 64]. More importantly, these data are crucial as they can serve as tool to document health issues and inequities, thus guiding and influencing decision makers to implement measures necessary to protect population and improve health systems [65].

*Early warning surveillance systems*
The government must use transdisciplinary participatory approaches to effectively stop disease outbreaks in the future and protect public health by identifying locally appropriate solutions while taking the economic effects into account, involving all stakeholders in a social agreement to strengthen biosecurity measures [66]. This collaborative strategy should encompass both academic and non-academic personnel, incorporating surveillance of non-communicable diseases and infections in both humans and animals [66]. For integrated surveillance-response mechanisms to be widely accepted, citizen engagement and a concentration on social sciences are essential.

*One Health approach*
The One Health aims to produce the best possible health outcomes for humans, animals, plants, and

the environment through a collaborative, multisectoral, and transdisciplinary approach. This multisectoral approach functions on a local, regional, national, and international scale [67]. The notion has become more significant as a result of things like population growth, climate change, patterns of land use, and an increase in international travel and trade. One Health tackles zoonotic diseases that can transfer from animals to people and recognizes that animals can act as early indicators of possible human illnesses [68]. Experts in human health, animal health, environmental health, and other fields must communicate with one another and work together to implement a One Health strategy. Incorporating law enforcement, policymakers, agriculture, communities, and pet owners, the One Health approach is well suited to prevent future pandemics by preventing zoonotic disease outbreaks, improving food safety and security, reducing antimicrobial-resistant infections, protecting global health security, and safeguarding biodiversity and conservation efforts [68, 69].

*Establishment of Vaccination drives*

Collaboration and technology exchange among stakeholders, such as the Coalition for Epidemic Preparedness Innovations (CEPI) and the National Institutes of Health (NIH), are necessary to improve global pandemic preparedness and response [70]. It is recommended that existing vaccine technological platforms be managed as open global commons to encourage local manufacturing and decentralized innovation. This can be done through technology transfer, capital investment, and capacity-building support, which are essential for increasing vaccine production capacity in low-resource environments, especially in Low-and Middle-Income Countries (LMICs) [70, 71]. In addition, it is important to help LMIC vaccine developers and manufacturers, through dedicated funding, as well as to improve regional skills, advocate for efficient manufacturing methods, and put supportive procurement rules into place [71].

*Employing Behavioral Models*

Future pandemic prevention and management depend on sustained behavior change. The need for funding research and initiatives that concentrate on comprehending and putting into practice the concepts of behavior modification is stressed by research on how human behavior contributed to COVID-19's spread and the significance of successfully persuading communities to embrace significant behavioral changes. This can be achieved using models like the COM-B model [72], which emphasizes the need for customized interventions and stresses the importance of capability, opportunity, and motivation in promoting behavior change. In addition to the significance of leadership, trust, and solidarity in creating motivation and adherence to pandemic control rules, the behavior change wheel framework is crucial for structuring treatments [72].

*Control of Wildlife*

The biosecurity of the wildlife trade and animal markets needs to be strengthened. The spread of prior infections, including 2019-nCoV, in China and around the world has been influenced by the wildlife trade [73]. Several wildlife trading bans were implemented during the COVID-19, but market biosecurity needs to be strengthened in terms of cleanliness and sanitation facilities and rules, as well as the source of animals traded at the market, in order to prevent the emergence of new diseases [74]. To control disease spread and avoid economic deterioration, effective integrated surveillance systems and inclusive response mechanisms involving a variety of stakeholders are crucial [73, 74].

*International collaboration*

By providing a coordinated and united response that cuts beyond national boundaries, international collaboration is essential for preventing future pandemics. Early warning systems, knowledge exchange, capacity building, coordinated research and development, equitable resource allocation, unified rules and regulations, diplomacy, and trust-building are all made possible by it [33]. Collaboration makes it easier to share knowledge about epidemiology, virology, public health initiatives, and ground-breaking research findings, allowing nations to learn from one another and implement successful disease prevention, surveillance, and control techniques into practice [75]. Through international cooperation, resource allocation and equity are also improved, ensuring that no nation is left unsupported and vulnerable. Through cooperative platforms like the World

Health Organization, standardized norms and guidelines are created, assuring uniformity in methods and enhancing collaboration [76].

## CONCLUSIONS

Pandemics have had such a long-lasting influence on populations, it is clear that successful prevention and response to new infectious diseases require national and international cooperation and coordination. Global collaboration, thorough public health education, data gathering and sharing, early warning surveillance systems, animal management procedures, and priority immunization efforts are all necessary components of a synergistic approach that incorporates lessons learned from previous experiences. By following these principles, we can build a more resilient and ready world that is able to successfully combat future pandemics.

**Funding**
We declare that no funding was received for this work.

**Competing interest**
The authors declare no conflict of interest.

**Author contributions**
All authors contributed equally to the writing of this paper. All authors have read and approved the final draft.

## REFERENCES

[1] Munnoli PM, Nabapure S, Yeshavanth G. Post-COVID-19 precautions based on lessons learned from past pandemics: a review. *J Public Health* (Bangkok). 2022; 30 (4): 973-981. doi: 10.1007/s10389-020-01371-3.
[2] Sampath S, Khedr A, Qamar S, et al. Pandemics Throughout the History. *Cureus*. 2021 Sep 20; https://www.cureus.com/articles/69273-pandemics-throughout-the-history.
[3] The Black Death. In: The Great Leveler [Internet]. Princeton University Press; 2017. p. 291-313. https://www.degruyter.com/document/doi/10.1515/9781400884605-013/html.
[4] Formenti B, Gregori N, Crosato V, Marchese V, Tomasoni LR, Castelli F. The impact of COVID-19 on communicable and non-communicable diseases in Africa: a narrative review. *Infez Med*. 2022; 30 (1): 30-40. http://www.ncbi.nlm.nih.gov/pubmed/35350264.
[5] Filip R, Gheorghita Puscaselu R, Anchidin-Norocel L, Dimian M, Savage WK. Global Challenges to Public Health Care Systems during the COVID-19 Pandemic: A Review of Pandemic Measures and Problems. *J Pers Med*. 2022; 12 (8): 1295. https://www.mdpi.com/2075-4426/12/8/1295.
[6] Gallo-Cajiao E, Lieberman S, Dolšak N, et al. Global governance for pandemic prevention and the wildlife trade. *Lancet Planet Health*. 202; 7 (4): e336-e345. doi: 10.1016/S2542-5196(23)00029-3.
[7] Lindahl JF, Grace D. The consequences of human actions on risks for infectious diseases: a review. *Infect Ecol Epidemiol*. 2015; 5 (1): 30048. doi: 10.3402/iee.v5.30048.
[8] Piret J, Boivin G. Pandemics throughout history. *Front Microbiol*. 2021; 11. https://www.frontiersin.org/articles/10.3389/fmicb.2020.631736/full.
[9] El-Sayed A, Kamel M. Climatic changes and their role in emergence and re-emergence of diseases. *Environ Sci Pollut Res*. 2020; 27 (18): 22336-22352. doi: 10.1007/s11356-020-08896-w.
[10] White RJ, Razgour O. Emerging zoonotic diseases originating in mammals: a systematic review of effects of anthropogenic land-use change. *Mamm Rev*. 2020; 50 (4): 33-352. doi: 10.1111/mam.12201.
[11] Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. *Ann N Y Acad Sci*. 2019; 1436 (1): 157-173. doi: 10.1111/nyas.13950.
[12] Rocklöv J, Dubrow R. Climate change: an enduring challenge for vector-borne disease prevention and control. *Nat Immunol*. 2020; 21 (5): 479-483. https://www.nature.com/articles/s41590-020-0648-y.
[13] Cutler SJ, Fooks AR, van der Poel WHM. Public health threat of new, reemerging, and neglected zoonoses in the industrialized world. *Emerg Infect Dis*. 2010; 16 (1): 1-7. https://wwwnc.cdc.gov/eid/article/16/1/08-1467_article.
[14] Oliveira M, Mason-Buck G, Ballard D, Branicki W, Amorim A. Biowarfare, bioterrorism and biocrime: A historical overview on microbial harmful applications. *Forensic Sci Int*. 2020; 314: 110366. https://linkinghub.elsevier.com/retrieve/pii/S0379073820302280.
[15] Van den Broucke S. Why health promotion matters to the COVID-19 pandemic, and vice versa. *Health Promot Int*. 2020; 35 (2): 181-186. https://academic.oup.com/heapro/article/35/2/181/5820891.
[16] Pitoyo CW. The Collateral Impacts of Pandemic. *Acta Med Indones*. 2020; 52 (4): 315-317. Available from: http://www.ncbi.nlm.nih.gov/pubmed/33377875.
[17] Dalekou S, Michaleas SN, Tsitsika AK, Karamanou M. Comparative study of pandemics and their impact on children and adolescents: COVID-19 and Spanish Flu. *Infez Med*. 2023; 31 (2): 131-139. http://www.ncbi.nlm.nih.gov/pubmed/37283646.
[18] Sabbatani S, Manfredi R, Fiorino S. The Justinian plague (part one). *Infez Med*. 2012; 20 (2): 125-139. http://www.ncbi.nlm.nih.gov/pubmed/22767313.

[19] Sáez A. La peste Antonina: una peste global en el siglo II d.C. *Rev Chil infectología*. 2016; 33 (2): 218-221. http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0716-10182016000200011&lng=en&nrm=iso&tlng=en.
[20] Jester B, Uyeki TM, Jernigan DB, Tumpey TM. Historical and clinical aspects of the 1918 H1N1 pandemic in the United States. *Virology*. 2019; 527: 32-37. https://linkinghub.elsevier.com/retrieve/pii/S0042682218303313.
[21] Honigsbaum M. Revisiting the 1957 and 1968 influenza pandemics. *Lancet*. 2020; 395 (10240): 1824-1826. https://linkinghub.elsevier.com/retrieve/pii/S0140673620312010.
[22] Saunders-Hastings P, Krewski D. Reviewing the history of pandemic influenza: understanding patterns of emergence and transmission. *Pathogens*. 2016; 5 (4): 66. http://www.mdpi.com/2076-0817/5/4/66.
[23] Akin L, Gözel MG. Understanding dynamics of pandemics. *Turkish J Med Sci*. 2020; 50 (SI-1): 515-519. https://journals.tubitak.gov.tr/medical/vol50/iss9/5.
[24] Malvy D, McElroy AK, de Clerck H, Günther S, van Griensven J. Ebola virus disease. *Lancet*. 2019; 393 (10174): 936-948. https://linkinghub.elsevier.com/retrieve/pii/S0140673618331325.
[25] Manirambona E, Shomuyiwa DO, Musa SS, Lucero-Prisno DE. Monkeypox among men who have sex with men in Africa: The need for testing and vaccination beyond stigma. *J Med Virol*. 2023; 95 (1). https://onlinelibrary.wiley.com/doi/10.1002/jmv.28121.
[26] Ibrahim NK. Epidemiologic surveillance for controlling Covid-19 pandemic: types, challenges and implications. *J Infect Public Health*. 2020; 13 (11): 1630-1608. https://linkinghub.elsevier.com/retrieve/pii/S1876034120306031.
[27] Omosigho PO, Okesanya JO, Olabode ON, et al. The emergence of BtSY2 Covid-like virus: A call for global preparedness. *J Taibah Univ Med Sci*. 2023; 18 (5): 1058-1060. https://linkinghub.elsevier.com/retrieve/pii/S1658361223000409.
[28] Ahmad A, Krumkamp R, Reintjes R. Controlling SARS: a review on China's response compared with other SARS-affected countries. *Trop Med Int Heal*. 2009; 14: 36-45. https://onlinelibrary.wiley.com/doi/10.1111/j.1365-3156.2008.02146.x.
[29] Zhou Y, Jiang H, Wang Q, Yang M, Chen Y, Jiang Q. Use of contact tracing, isolation, and mass testing to control transmission of covid-19 in China. *BMJ*. 2021; n2330. doi: 10.1136/bmj.n2330.
[30] Okesanya OJ, Manirambona E, Buban JMA, Olabode ON, Lucero-Prisno DE. Coronavirus Disease 2019 emergency is over but the pandemic is not: implications for a new global order. *Int J Surg Glob Heal*. 2023; 6 (4). doi: 10.1097/GH9.0000000000000207.
[31] Javed S, Chattu VK. Strengthening the COVID-19 pandemic response, global leadership, and international cooperation through global health diplomacy. *Heal Promot Perspect*. 2020; 10 (4): 300-305. https://hpp.tbzmed.ac.ir/Article/hpp-32567.
[32] Ochani R, Asad A, Yasmin F, et al. COVID-19 pandemic: from origins to outcomes. A comprehensive review of viral pathogenesis, clinical manifestations, diagnostic evaluation, and management. *Infez Med*. 2021; 29 (1): 20-36. http://www.ncbi.nlm.nih.gov/pubmed/33664170.
[33] Bump JB, Friberg P, Harper DR. International collaboration and covid-19: what are we doing and where are we going? *BMJ*. 2021; 180. doi: 10.1136/bmj.n180.
[34] Abdalla W, Renukappa S, Suresh S. Managing COVID-19-related knowledge: A smart cities perspective. *Knowl Process Manag*. 2023; 30 (1): 87-109. doi: 10.1002/kpm.1706.
[35] Andreoni M, Bonanni P, Cossarizza A, et al. The future for COVID-19 vaccines: public health assessment and perspectives based on scientific evidence. *Infez Med*. 2022; 31(1): 1-5. http://www.ncbi.nlm.nih.gov/pubmed/36908384
[36] Riaz MMA, Ahmad U, Mohan A, et al. Global impact of vaccine nationalism during COVID-19 pandemic. *Trop Med Health*. 2021; 49 (1): 101. doi:10.1186/s41182-021-00394-0.
[37] WHO. WHO and the Global Fund announce commitment for enhanced collaboration. https://www.who.int/news/item/08-06-2023-who-and-the-global-fund-announce-commitment-for-enhanced-collaboration.
[38] Fanning JP, Murthy S, Obonyo NG, Baillie JK, Webb S, Dalton HJ, et al. Global infectious disease research collaborations in crises: building capacity and inclusivity through cooperation. *Global Health*. 2021; 17 (1): 84. doi: 10.1186/s12992-021-00731-2.
[39] Sundararaman T, Muraleedharan VR, Ranjan A. Pandemic resilience and health systems preparedness: lessons from COVID-19 for the twenty-first century. *J Soc Econ Dev*. 2021; 23 (S2): 290-300. doi: 10.1007/s40847-020-00133-x.
[40] Alnasser AHA, Al-Tawfiq JA, Al Kalif MSH, et al. Impact of COVID-19 severity on health-related quality of life among Saudi adult patients. *Infez Med*. 2022; 30 (2): 223-230. http://www.ncbi.nlm.nih.gov/pubmed/35693056.
[41] Omosigho PO, Okesanya OJ, Olaleke NO, Eshun G, Lucero-Prisno DE. Multiple burden of infectious disease outbreaks: Implications for Africa healthcare system. *J Taibah Univ Med Sci*. 2023; 18 (6): 1446-1448. https://linkinghub.elsevier.com/retrieve/pii/S1658361223000999.
[42] Al-Shorbaji N. Improving Healthcare Access through Digital Health: The Use of Information and Communication Technologies. In: Healthcare Access. *IntechOpen*; 2022. https://www.intechopen.com/chapters/78328.
[43] WHO. Covid-19 Strategic Preparedness and Response Plan for the Who African Region. *World Heal Organ*. 2021; 1 (January) 0-27. https://www.afro.who.int/sites/default/files/2021-04/WHO AFR Covid-19 2021 SRP_Final_16042021.pdf.
[44] Lee JM, Jansen R, Sanderson KE, et al. Public health

emergency preparedness for infectious disease emergencies: a scoping review of recent evidence. *BMC Public Health*. 2023; 23 (1): 420. doi: 10.1186/s12889-023-15313-7.
[45] Khan Y, O'Sullivan T, Brown A, et al. Public health emergency preparedness: a framework to promote resilience. *BMC Public Health*. 2018; 18 (1): 1344. doi: 10.1186/s12889-018-6250-7.
[46] Jamison DT. Disease Control Priorities, 3rd edition: improving health and reducing poverty. *The Lancet*. 2018; 391: 11-14.
[47] Dubé È, Labbé F, Malo B, Pelletier C. Public health communication during the COVID-19 pandemic: perspectives of communication specialists, healthcare professionals, and community members in Quebec, Canada. *Can J Public Heal*. 2022; 113 (S1): 24-33. doi: 10.17269/s41997-022-00697-7.
[48] Cooks EJ, Vilaro MJ, Dyal BW, et al. What did the pandemic teach us about effective health communication? Unpacking the COVID-19 infodemic. *BMC Public Health*. 2022; 22 (1): 2339. doi: 10.1186/s12889-022-14707-3.
[49] Bravo P, Martinez-Pereira A, Fernández-González L, Dois A. What is needed to effectively communicate risk during a health crisis? A qualitative study with international experts based on the COVID-19 pandemic. *BMJ Open*. 2023; 13 (5): e067531. doi: 10.1136/bmjopen-2022-067531.
[50] Agarwal R, Gaule P. What drives innovation? Lessons from COVID-19 R&D. *J Health Econ.* 2022; 82: 102591. doi: 10.1016/j.jhealeco.2022.102591.
[51] Moore KA, Leighton T, Ostrowsky JT, Anderson CJ, Danila RN, Ulrich AK, et al. A research and development (R&D) roadmap for broadly protective coronavirus vaccines: A pandemic preparedness strategy. *Vaccine*. 2023; 41 (13): 2101-2112. https://linkinghub.elsevier.com/retrieve/pii/S0264410X23001676.
[52] Commission on a Global Health Risk Framework for the Future; National Academy of Medicine, Secretariat. The Neglected Dimension of Global Security: A Framework to Counter Infectious Disease Crises. Washington (DC): National Academies Press (US); 2016; 16. doi: 10.17226/21891.
[53] Tabish SA. Covid-19 Pandemic: Emerging Perspectives and Future Trends. *J Public health Res*. 2020; 9 (1): jphr.2020.1786. doi: 10.4081/jphr.2020.1786.
[54] Jarrett M, Garrick R, Gaeta A, Lombardi D, Mayo R, McNulty P, et al. Pandemic Preparedness: COVID-19 Lessons Learned in New York's Hospitals. *Jt Comm J Qual Patient Saf*. 2022; 48 (9): 475-491. https://linkinghub.elsevier.com/retrieve/pii/S1553725022001180.
[55] American Hospital Association. Embracing Flexibility and Adaptability in the Face of COVID-19. 2022. Available from: https://www.aha.org/news/healthcareinnovation-thursday-blog/2022-02-17-embracing-flexibility-and-adaptability-face.
[56] Önal U, Tüzemen Ü, Kazak E, et al. Effects of COVID-19 pandemic on healthcare-associated infections, antibiotic resistance and consumption rates in intensive care units. *Infez Med*. 2023; 31 (2): 195-203. http://www.ncbi.nlm.nih.gov/pubmed/37283640.
[57] Manirambona E, Hague O, Trajano LF, et al. COVID-19 Vaccines: Ensuring Social Justice and Health Equity among Refugees in Africa. *Ann Glob Hea*l. 2021; 87 (1). https://annalsofglobalhealth.org/articles/10.5334/aogh.3415/.
[58] Manirambona E, Wilkins L, Lucero-Prisno III DE. COVID-19 and its threat to refugees in Africa. *Heal Promot Perspect*. 2021; 11 (3): 263-266. https://hpp.tbzmed.ac.ir/Article/hpp-34397.
[59] Manirambona E, Musa SS, Irakoze S, et al. The impact of COVID-19 on international development aid and health systems strengthening in low-income countries. *Ann Med Surg*. 2022; 82. https://journals.lww.com/10.1016/j.amsu.2022.104772.
[60] Mujica O, Brown C, Victora C, Goldblatt P, Barbosa da Silva J. Health inequity focus in pandemic preparedness and response plans. *Bull World Health Organ*. 2022; 100 (02): 91-91. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8795854/pdf/BLT.21.287580.pdf.
[61] Manzi A, Henley P, Lieberman H, et al. Designing and implementing equity-based pandemic preparedness and response learning modules: lessons from a multi-country short-course. *Glob Health Action*. 2022; 15(1). doi: 10.1080/16549716.2022.2104319.
[62] Haldane V, De Foo C, Abdalla SM, et al. Health systems resilience in managing the COVID-19 pandemic: lessons from 28 countries. *Nat Med*. 2021; 27 (6): 964-980. https://www.nature.com/articles/s41591-021-01381-y.
[63] Shadbolt N, Brett A, Chen M, Marion G, McKendrick IJ, Panovska-Griffiths J, et al. The challenges of data in future pandemics. *Epidemics.* 2022; 40: 100612. https://linkinghub.elsevier.com/retrieve/pii/S1755436522000548.
[64] Khan MS, Dar O, Erondu NA, Rahman-Shepherd A, Hollmann L, Ihekweazu C, et al. Using critical information to strengthen pandemic preparedness: the role of national public health agencies. *BMJ Glob Heal*. 2020; 5 (9): e002830. https://gh.bmj.com/lookup/doi/10.1136/bmjgh-2020-002830.
[65] Manirambona E. Health Policy and Systems Research in Sub-Saharan Africa during the COVID-19 Pandemic. *Ann Public Heal*. 2022 https://mediterraneanjournals.com/index.php/aph/article/view/609.
[66] Zinsstag J, Utzinger J, Probst-Hensch N, Shan L, Zhou XN. Towards integrated surveillance-response systems for the prevention of future pandemics. *Infect Dis Poverty*. 2020; 9 (1): 140: https://idpjournal.biomedcentral.com/articles/10.1186/s40249-020-00757-5.
[67] Ghai RR, Wallace RM, Kile JC, Shoemaker TR, Vieira AR, Negron ME, et al. A generalizable one health

framework for the control of zoonotic diseases. *Sci Rep*. 2022; 12 (1): 8588.https://www.nature.com/articles/s41598-022-12619-1.
[68] Olaleke O, Okesanya O, Abioye S, Othoigbe M, Matthew E, Emery M, et al. The Forms, Challenges and Strength of the Monkeypox Surveillance System in Nigeria. *Ann Heal Res*. 2022; 8 (4): 269-276. https://annalsofhealthresearch.com/index.php/ahr/article/view/458.
[69]. Osterhaus, A.D.M.E., Vanlangendonck, C., Barbeschi, M. et al. Make science evolve into a One Health approach to improve health and security: a white paper. *One Health Outlook*. 2020; 2 (1): 6. https://doi.org/10.1186/s42522-019-0009-7.
[70] Farlow A, Torreele E, Gray G, et al. The future of epidemic and pandemic vaccines to serve global public health needs. *Vaccines.* 2023; 11 (3): 690. https://www.mdpi.com/2076-393X/11/3/690.
[71] Kumraj G, Pathak S, Shah S, et al. Capacity Building for vaccine manufacturing across developing countries: the way forward. *Hum Vaccin Immunother*. 2022; 18 (1). doi: 10.1080/21645515.2021.2020529.
[72] Michie S, West R. Sustained behavior change is key to preventing and tackling future pandemics. *Nat Med*. 2021; 27 (5): 749-752. https://www.nature.com/articles/s41591-021-01345-2.
[73] Daszak P, Olival KJ, Li H. A strategy to prevent future epidemics similar to the 2019-nCoV outbreak. *Biosaf Heal*. 2020; 2 (1): 6-8: https://linkinghub.elsevier.com/retrieve/pii/S2590053620300161.
[74] Gallo-Cajiao E, Lieberman S, Dolšak N, et al. Global governance for pandemic prevention and the wildlife trade. *Lancet Planet Heal*. 2023; 7 (4): e336-45. https://linkinghub.elsevier.com/retrieve/pii/S2542519623000293.
[75] Bonilla-Aldana DK, Acevedo-López D, Aristizábal-Carmona BS, Díaz-García FA, Sarmiento-Cano CC, Gutiérrez-Soleibe S, et al. Molecular and serological prevalence of Coronavirus in Chiropterans: A systematic review with meta-analysis. *Infez Med.* 2021; 29 (2): 181-190. http://www.ncbi.nlm.nih.gov/pubmed/34061782.
[76] Mølhave M, Agergaard J, Wejse C. Clinical Management of COVID-19 Patients – An Update. *Semin Nucl Med*. 2022; 52 (1): 4-10. https://linkinghub.elsevier.com/retrieve/pii/S0001299821000362.